"VARIATIONS IN ELECTRICAL PROPERTIES INDUCED BY STRESS ALONG THE SAN ANDREAS FAULT AT PARKFIELD, CALIFORNIA"

FINAL REPORT FOR 1998
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STEPHEN PARK
University of California, Riverside
The Institute of Geophysics and Planetary Physics
Riverside, California 92521

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Abstract

'Variations in electrical resistivity have been monitored in Parkfield since 1988 with a telluric array. This array provides is designed to detect relative changes in resistivity at levels of 1% over periods of days to weeks and 0.1% over periods of months to years. This year has been characterized by a lack of significant tectonic activity (earthquakes, strain, stress) which has resulted in a lack of any detectable variations in electrical properties. Data from 1998 continue to show stable responses except for changes in associated with system problems, corresponding to a general lack of significant tectonic activity. The earthquake activity in September, 1998 that led to a D level alert (a level A alert under the former criteria) did not result in any variations in our responses.

Introduction

Changes of electrical resistivity due to simple elastic deformation are commonly observed prior to failure of rocks in the laboratory [Brace, 1975]. This mechanism should also result in a large coseismic resistivity change, but these are not observed in field experiments [Park et al., 1993]. Instead, precursory [Zhao et al., 1991] and post-seismic changes [Mackie, et al., 1992] have been reported. The general lack of coseismic signals suggests that elastic deformation of the rock is probably not the likely cause of resistivity changes. Alternatively, stress corrosion has been suggested as a cause for resistivity changes [Madden, personal communication, 1986]. Such a mechanism would result in slow changes in resistivity over periods of years, and would not be observed in typical laboratory measurements which have time spans of hours [Park et al., 1993]. Changes in the field span years [Madden et al., 1993; Zhao, et al., 1991], so stress corrosion may be a more viable mechanism for field observations. In summary, evidence shows that precursory changes of resisitivity are sometimes observed but that explanatory mechanisms are only hypothetical at this point.

Monitoring Array

Variations in the telluric coefficients are recorded with the monitoring array in Parkfield (Figure 1). Natural telluric currents are induced in the earth by a fluctuating magnetic field and are subsequently redistributed by the resistivity structure. If the wavelength of the source field is much larger than the dimension of the array, then the electric fields are related linearly: $C = xA + yB$. A, B, and C are time-varying electric fields measured on the dipoles in Figure 1. X and y are the telluric coefficients which should vary when changes in the electrical resistivity occur. The basic purpose of this experiment is to yield daily estimates of the telluric coefficients which are stable to O(1%) or less. This stability is achieved by projecting the daily fluctuation of the telluric coefficients on the average eigenvectors of the electric field were needed to achieve the desired stability. These projections examine the changes parallel and perpendicular to the fault and eliminates scatter due to polarization changes in the source.

In November 1997, a Quanterra 4128 seismic data logger was installed in Parkfield and began digitizing the electric field data. After several months of recording data simultaneously on the

Data Translation (the existing system) and Quanterra systems, cross channel calibrations were run to compare the two systems. At that time, instabilities were identified in one of the reference channels (Dipole 7). The problems were traced to an isolation circuit which has now been redesigned. After some mechanical problems with the circuit boards for this isolation circuit, the Quanterra system is aquiring data that is comparable to the existing system. Analysis of one month's worth of data in mid 1998 shows that the isolation circuit is now stable (Table 1), and that use of the Quanterra system results in comparable estimates of transfer functions. Maximum errors in estimates of the gains for the isolation circuits are approximately 0.1% (Table 1) and closer to 0.05% in most cases. (In comparison, the raw telluric transfer functions vary by as much as 10% during the test period and typically by 1%.) However, the telluric coefficients are always more variable than the eigenvector projections (Park, 1991). The similarity in responses between the two data acquisition systems despite the fact that one is a 24 bit system and the other a 16 bit system is consistent with previous tests which have identified the principal source of noise to be the telephone lines used as electric field antennae. I anticipate that the Quanterra will be our primary acquisition system by the end of 1998 and that the existing system will be run only as a backup.

<u>1998 Results</u>

Results of the analysis of the first 3 quarters of 1998 for Dipoles 1 through 6 are shown in Figures 2 through 7. The projections of the daily fluctuation of the telluric coefficient perpendicular and parallel to the San Andreas fault (P1 and P2, respectively) and the coherency as a measure of the data quality are plotted. The coherency is computed between the observed dipole signal and that predicted from the telluric coefficients and the base dipoles (7 and 8, Figure 1). The data are smoothed with a weighted, running 9-day average in order to reduce scatter and provide error bars. The uncertainties shown are based on 95% confidence intervals. Only deviations for which confidence intervals do not overlap with adjacent intervals are considered significant. On that basis, there have been no significant deviations so far in 1998. We note that

The spotty data in the 2nd and 3rd quarters (days 250-290) resulted from problems with the power system at Halliburton. Apparently, the main breaker for the house developed a defect that resulted in a failure of the UPS to which our equipment is connected. Simultaneous with this, the isolation circuit used in line with the Quanterra developed a mechanical flaw on dipole 7 (one of the two reference dipoles). The circuit problem has been fixed, but the stability of the main power system is still uncertain at this time. While the Quanterra has a battery backup that permits it to continue sampling data when the main power is lost, the rest of the circuitry requires ac power. On a more positive note, the exceptionally wet El Niño winter did not degrade our data any more than as is usual due to leakage of moisture into the telephone cables (first 120 days of 1998).

A pair of M3.5 earthquakes struck on September 16, 1998 about 10 km northwest of Parkfield. Under the new alert rules, this qualified as a level D alert. Under the previous rules, it qualified as a level A alert. These earthquakes were associated with strain changes that began three days earlier (Table 2). While we reported anomalous electric fields on September 4 (24898), we saw no unusual behavior prior to and during the earthquake. The only possibly unusual occurrence is the poor data quality observed on dipoles 2 and 5 resulting in the lack of projections during this time. We do note that dipole 6, which straddles the region of the 1966 earthquake, showed no changes during this time.

Data Repository

The original plan was to reformat all 10 years of Parkfield data into SEED format and place the data in archives at the Berkeley seismic station. However, it is now apparent that the original data files from the experiment can be used in binary form on a Unix platform. These data will be archived on anonymous ftp on vortex.ucr.edu in pub/pkfld by the end of 1998. Documentation of timing and system calibrations will need to be included with the data.

Conclusions

The first step in understanding the variation of resistivity and the utility of this variation as a precursor to earthquakes is to measure changes in an active fault zone. Parkfield is a favorable location to monitor such phenomena. The region is seismically active, and has recurring earthquakes. Diverse monitoring experiments are already situated in the region, so integration of several types of data is possible. This integration will lead to a better understanding of the mechanics of earthquakes, of changes of physical properties prior to the earthquakes, and finally of how to reliably use these precursors to predict earthquakes.

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Table 1 - Comparison of Data Translation and Quanterra Channels

Channel	Transfer function $(D_Q(t)/D_{DT}(t))$	Standard error
1	0.99757	0.00046
2	0.99833	0.00076
3	0.99717	0.00055
4	0.99887	0.00099
5	0.99601	0.00108
6	0.99636	0.00040
7	0.99704	0.00118
8	0.99648	0.00068

Table 2 - Tectonic Activity for 1998

Date	Julian Date	Tectonic Event	Alert Level
05-02-98	12298	13.7 cm water level drop in wmm4	
		-17 $n\epsilon$ areal strain @ Eades	D
		-6 $n\epsilon$ $\gamma 1$ strain @ Frolich	
		-45 $n\epsilon$ areal, -10 $n\epsilon$ $\gamma 1$, -5 $n\epsilon$ $\gamma 2$ xva dilatometer (?)	
05-15-98	13598	M2.0 @ 4.37 km depth near Gold Hill	
08-02-98	21498	-7.6 cm water level drop in wmm4	
		creep at xmm1,xmd1	D
		-21 $n\epsilon$ areal, -10 $n\epsilon$ $\gamma 1$, +16 $n\epsilon$ $\gamma 2$ @ Frolich tensor strain	
		8.5 $n\epsilon$ dilatometer at Frolich	
09-16-98	25998	2 M3.5 earthquakes at 7.7 km depth 10 km NW of Parkfield (MM box)	D
		10 $n\epsilon$ compression at Donnalee and 13 $n\epsilon$ compression at Vineyard Canyon tensor strain meters	
		60-100 $n\epsilon$ strain change beginning 09-13-98 (25698) and strain rate change at Gold Hill on 09-14-98	
		15 $n\epsilon$ compression followed by 30 $n\epsilon$ extension over next two days.	

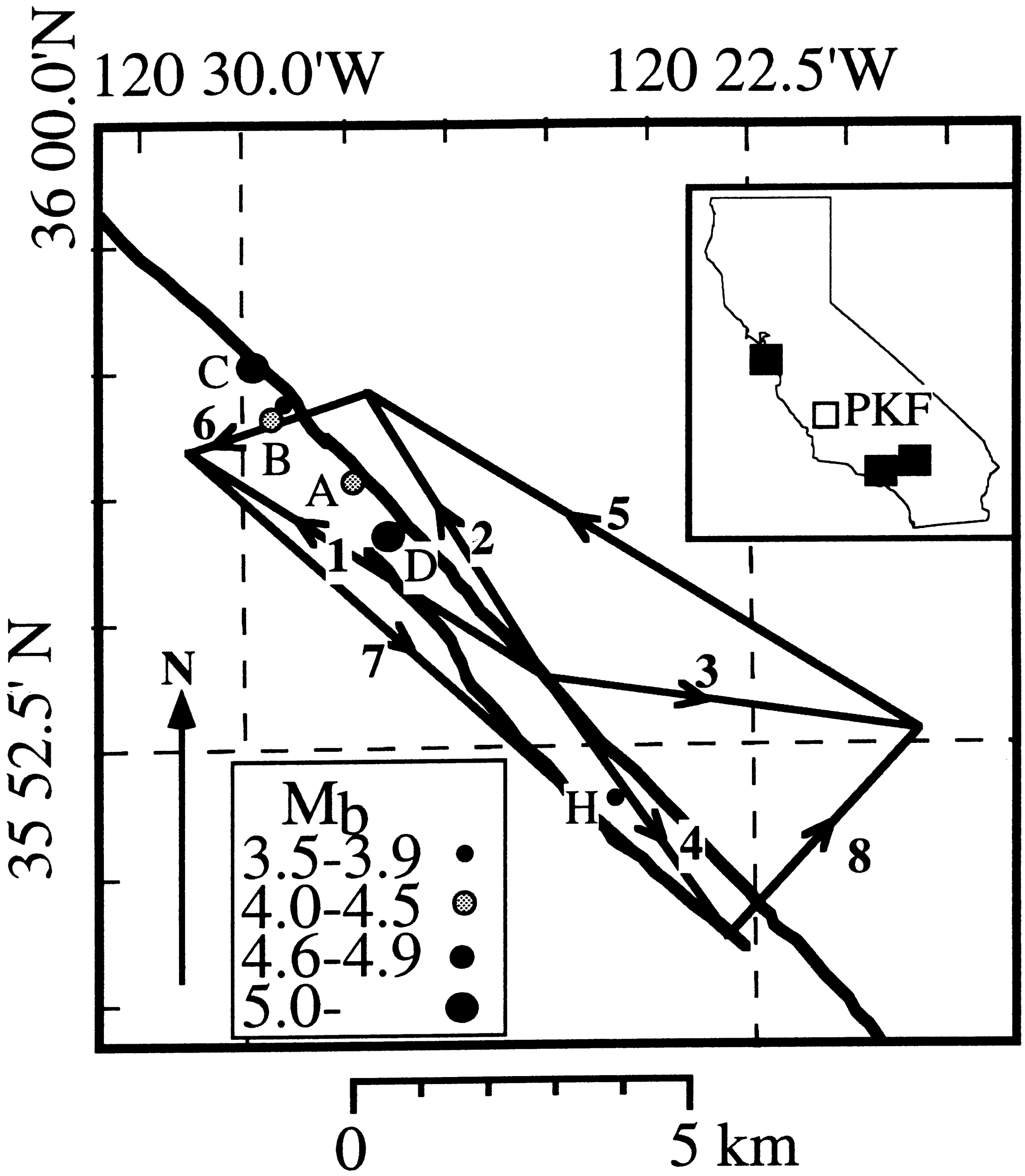

Figure 1 - Location map for telluric array in Parkfield. Dipoles 1 through 8 are created electronically by differencing potentials from 5 electrodes. Earthquakes with $M_b > 3.5$ since 1988 are shown.

Figure 2 - Smoothed projections P1 (upper plot) and P2 (middle plot) on average eigenvectors for Dipole 1 for 1998. P1 is in a northeasterly direction, and P2 is in a northwesterly direction parallel to the fault. Note that the range is 2% on the major projection and 5% on the minor projection. Coherencies are shown in the lowest plot with a range from .998 to 1.000. Error bars are standard deviations derived by averaging projections from a nine day window bracketing the smoothed projection.

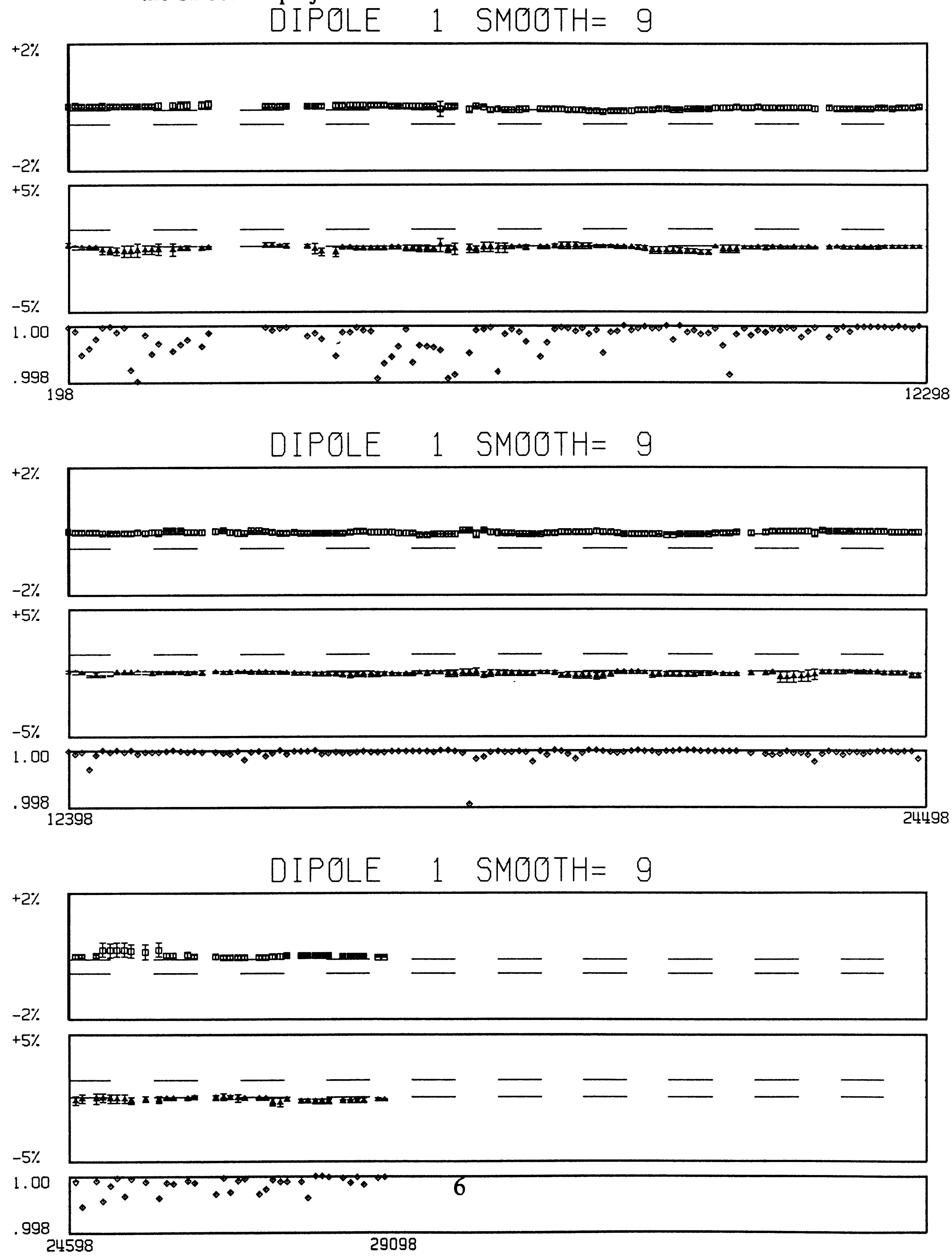

Figure 3 - Smoothed projections for Dipole 2 for 1998. See caption of Figure 2 for explanation.

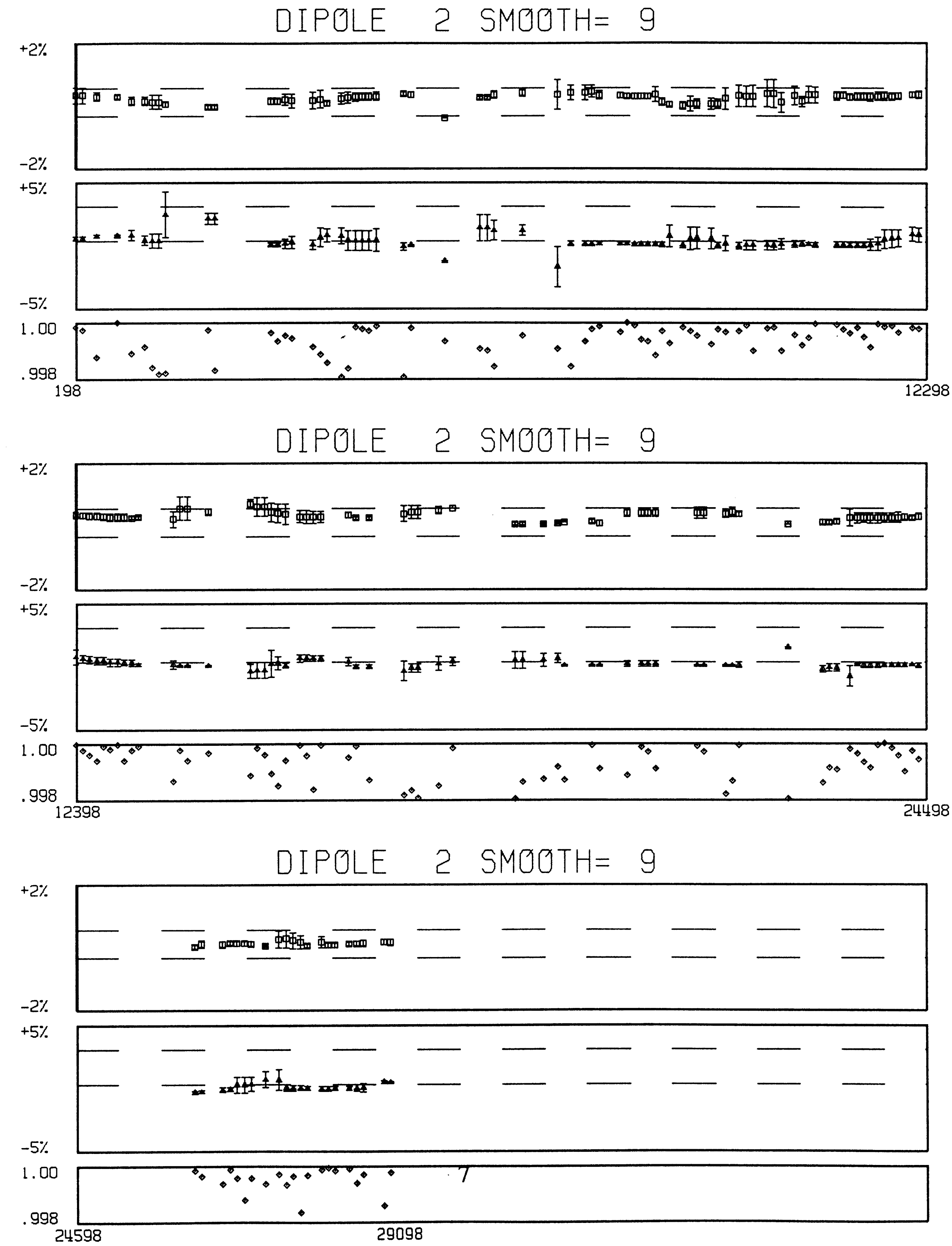

Figure 4 - Smoothed projections for Dipole 3 for 1998. See caption of Figure 2 for explanation.

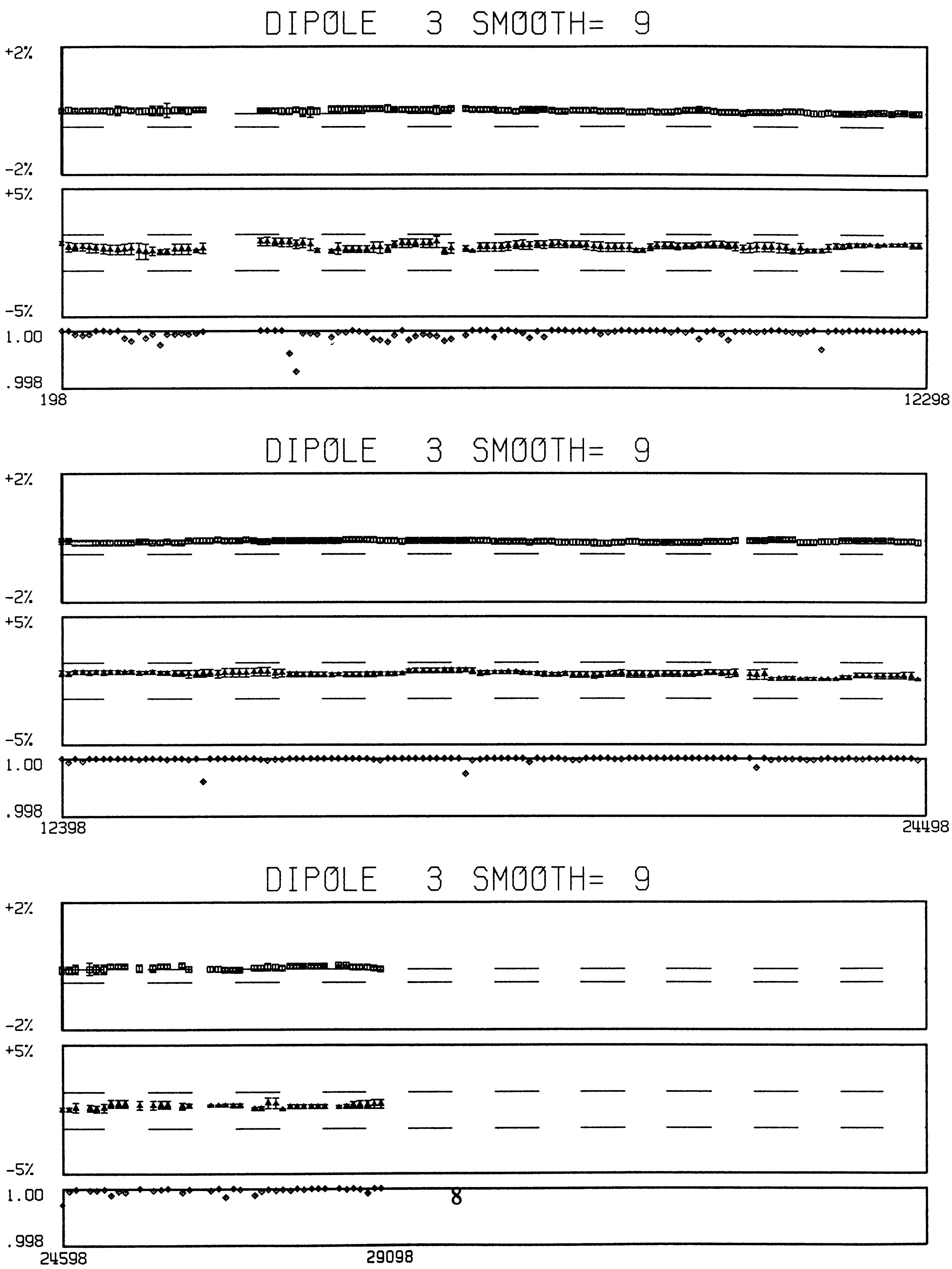

Figure 5 - Smoothed projections for Dipole 4 for 1998. See caption of Figure 2 for explanation.

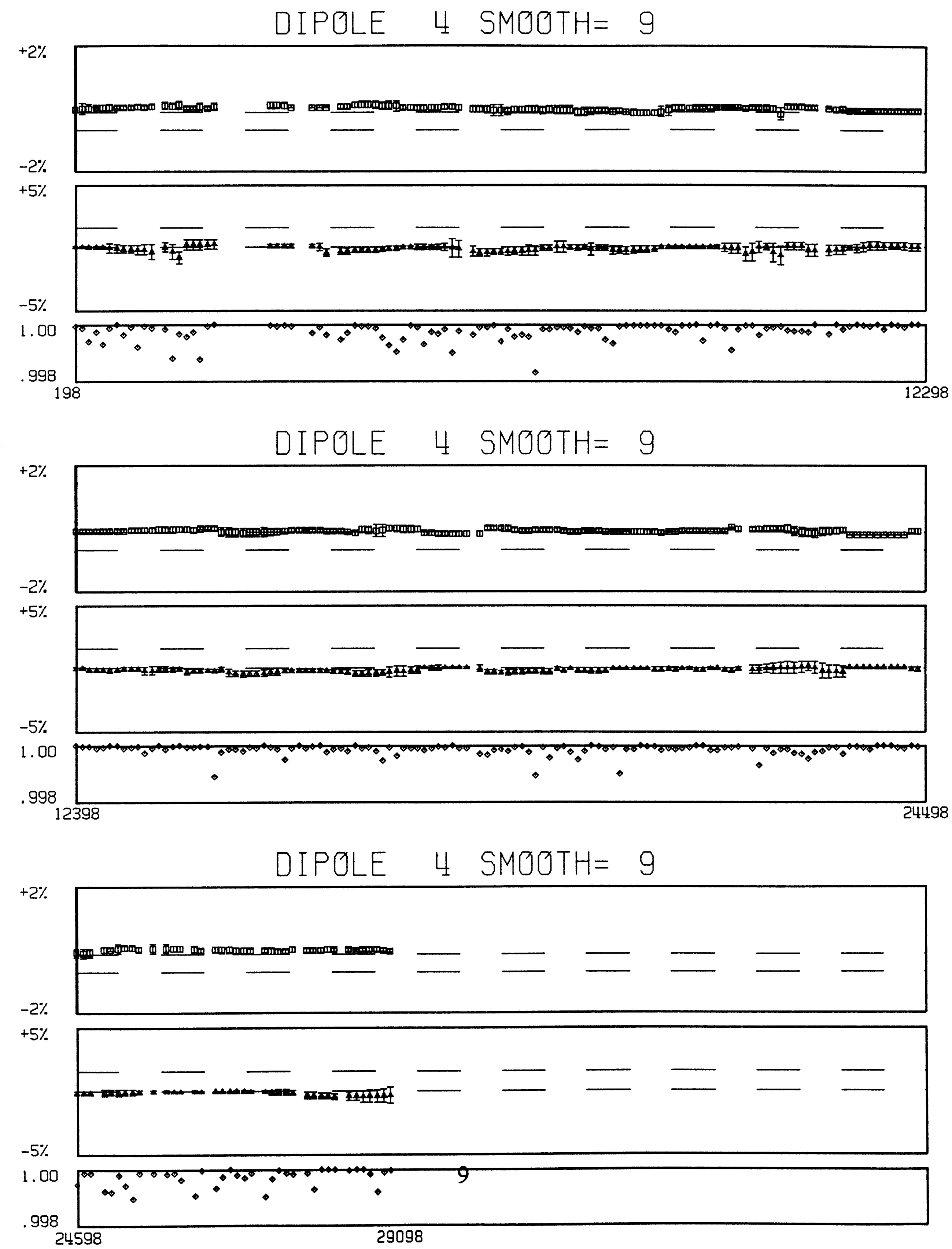

Figure 6 - Smoothed projections for Dipole 5 for 1998. See caption of Figure 2 for explanation.

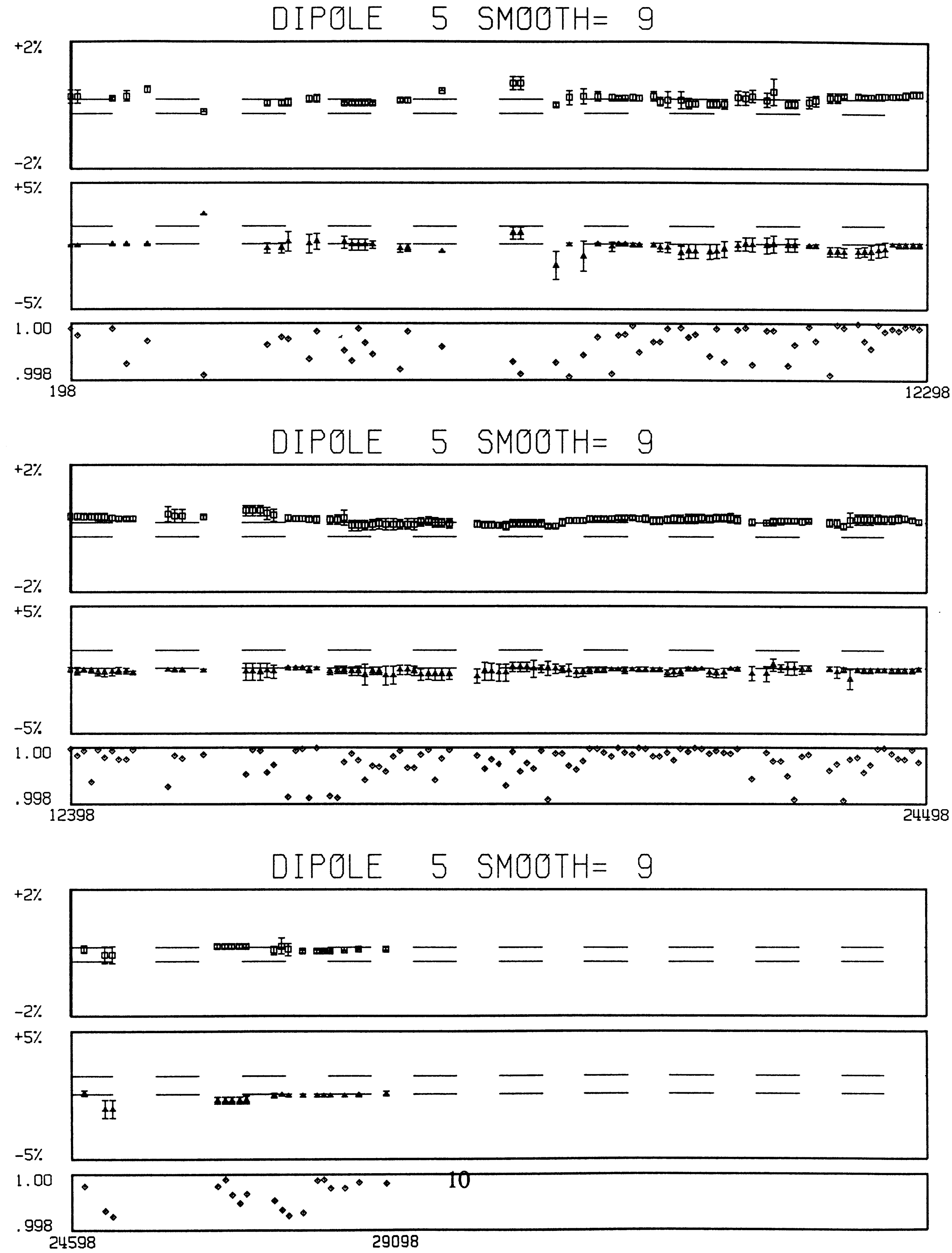

Figure 7 - Smoothed projections for Dipole 6 for 1998. See caption of Figure 2 for explanation.

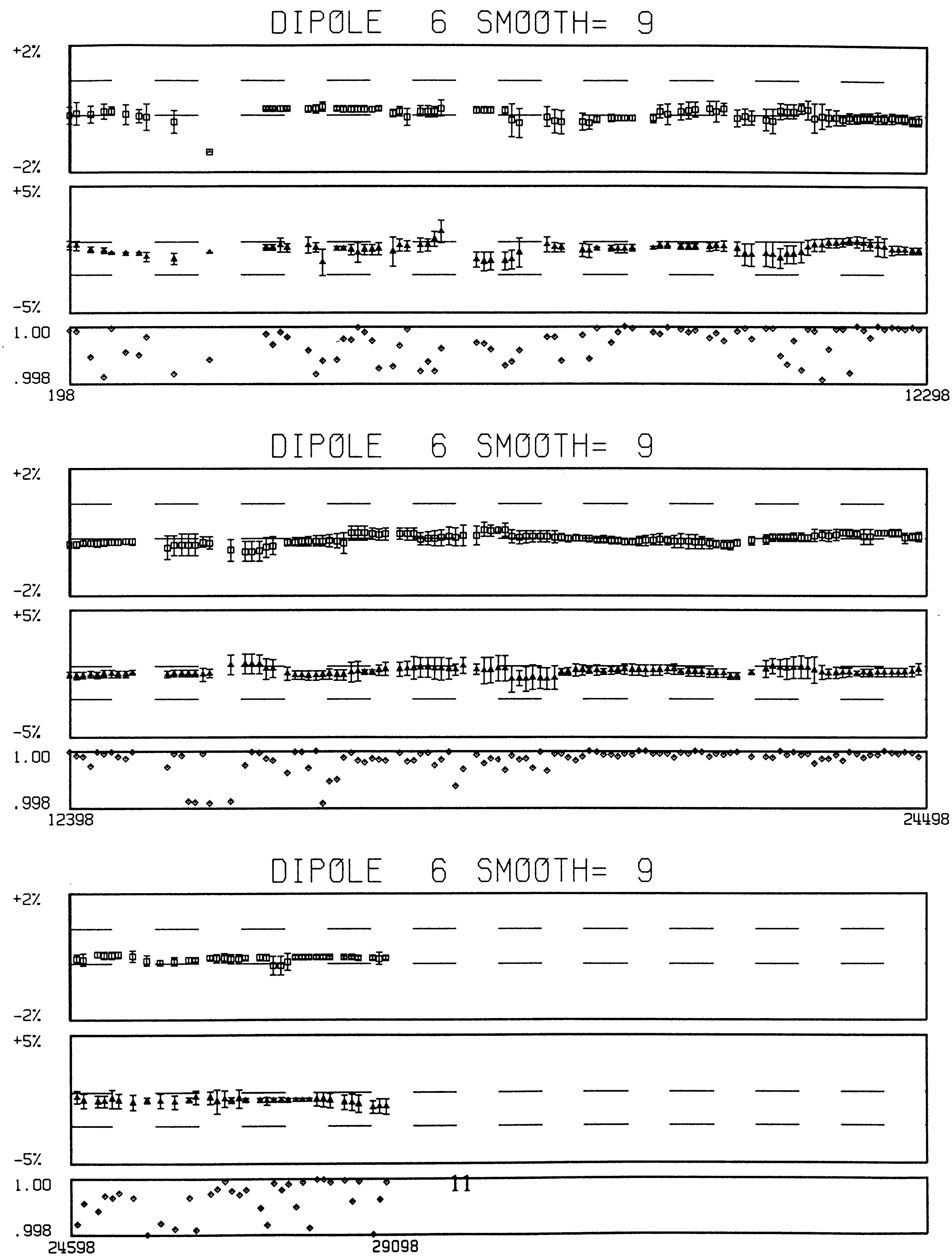

Figure 8 - Unsmoothed coefficients of dipoles 2 and 3 in the loop test 5=x2-y3. Scales on the coefficients are ±4% from expected values of 1.0 or -1.0. Coherency between observed dipole 5 and that predicted from x2-y3 is plotted between 0.999 and 1.000. The corresponding noise levels are typically below the digitizer noise of 1.0 mV. With the exception of a few deviations, the loop tests result in very stable coefficients.

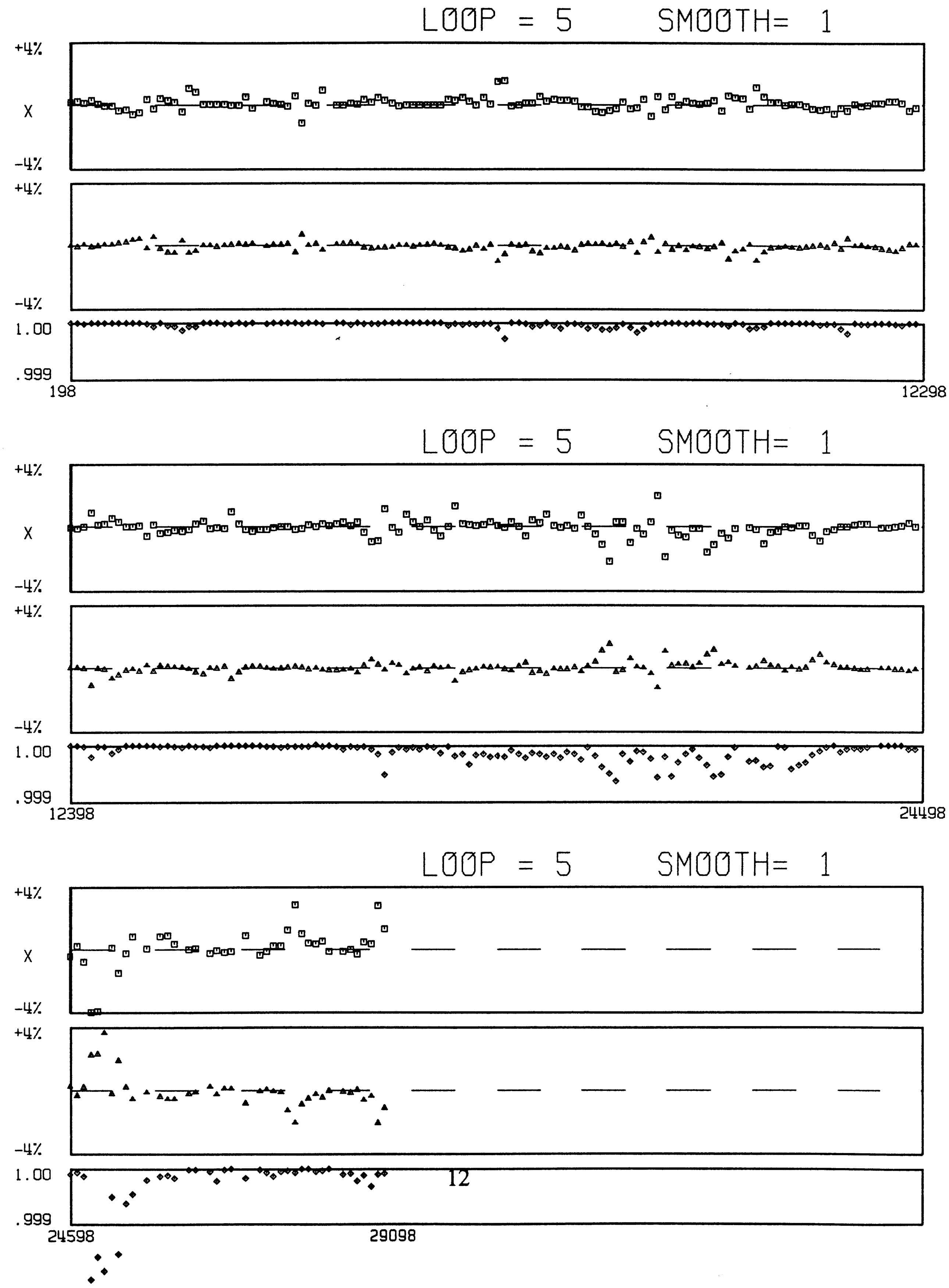

Figure 9 - Unsmoothed coefficients of dipoles 1 and 2 in the loop test 6=x1-y2. See caption of Figure 8 for explanation.

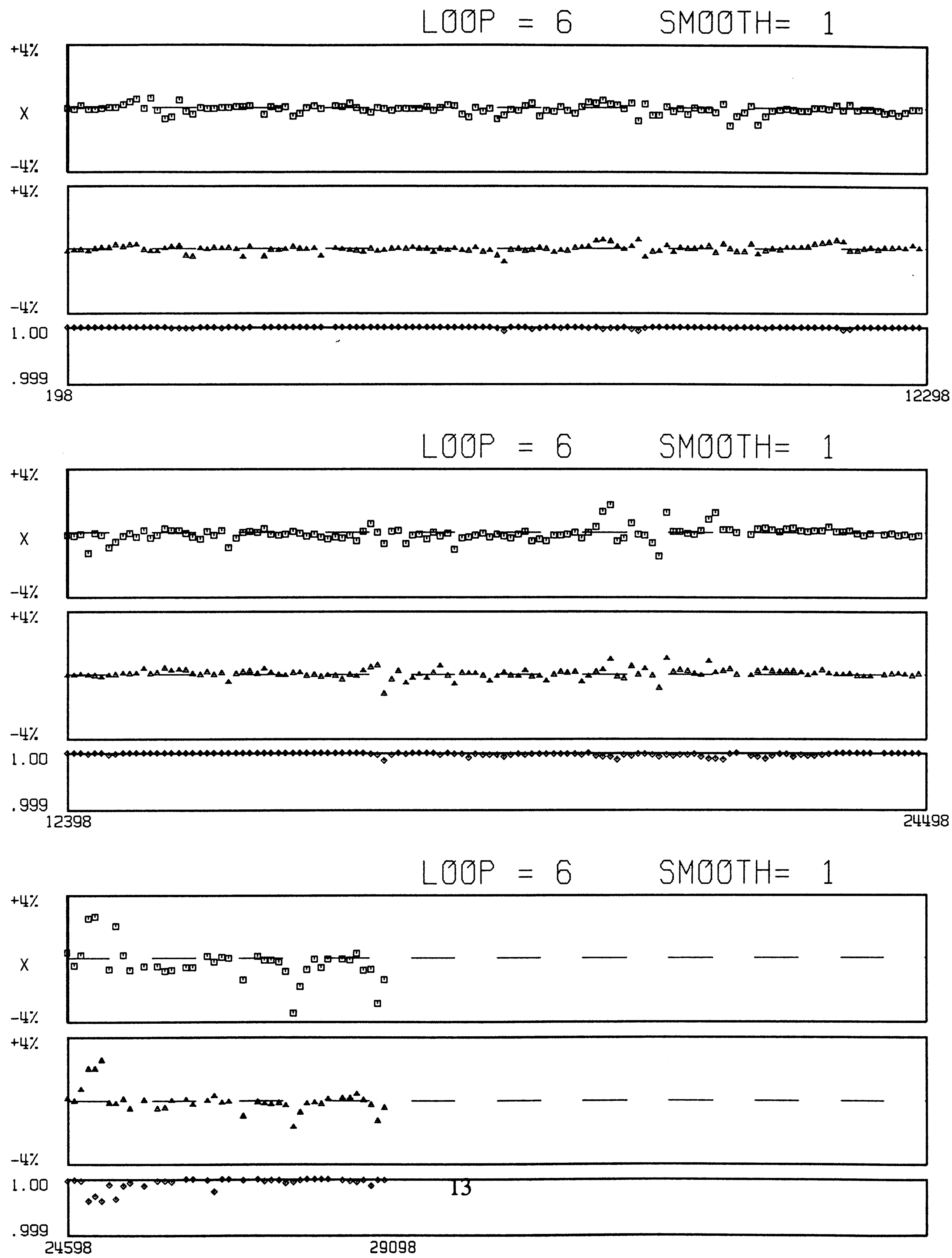

Figure 10 - Unsmoothed coefficients of dipoles 4 and 1 in the loop test 7=x4-y1. See caption of Figure 8 for explanation.

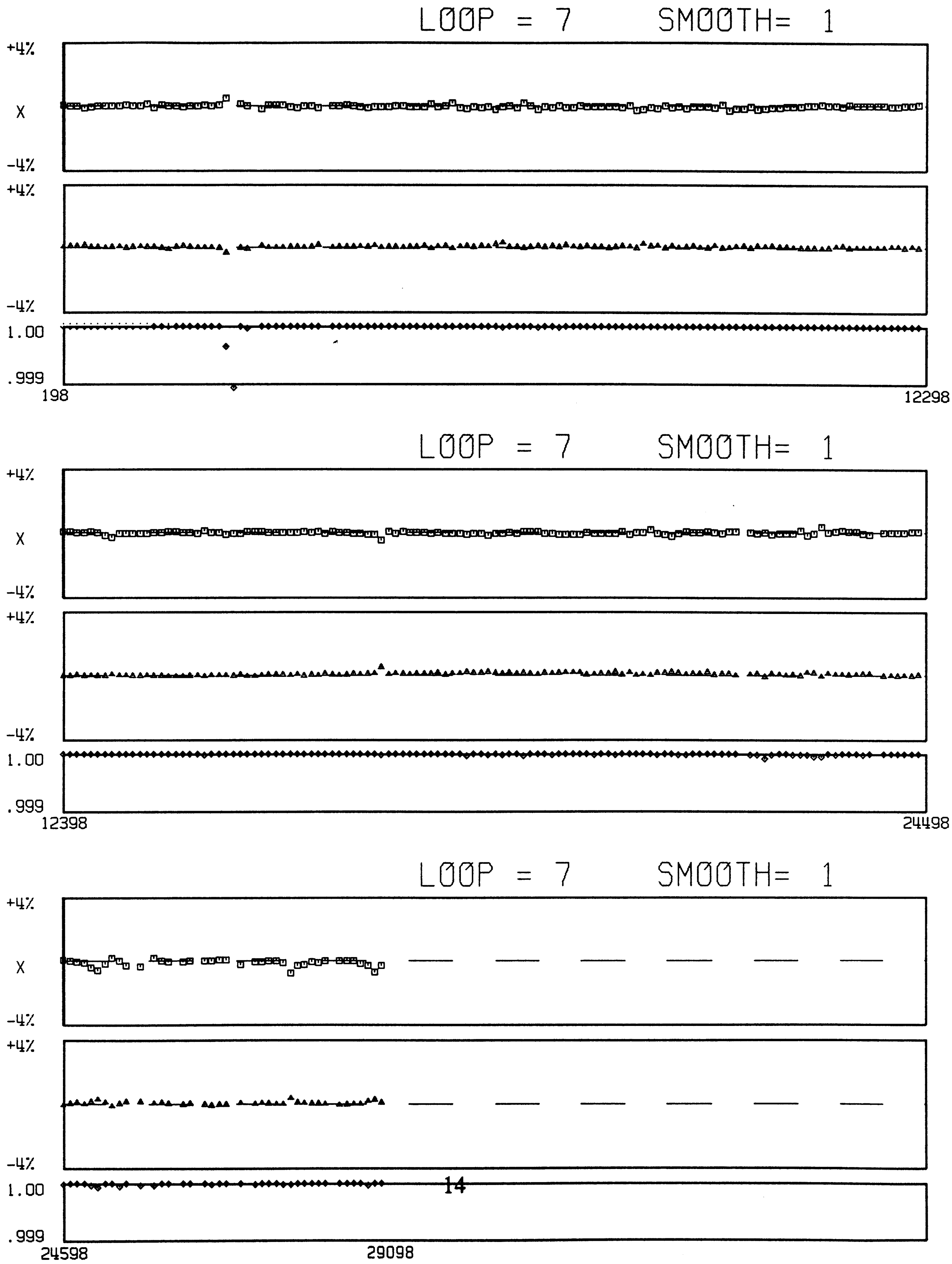

Figure 11 - Unsmoothed coefficients of dipoles 3 and 4 in the loop test 8=x3-y4. See caption of Figure 8 for explanation.